FORT WORTH

TRANSPORTATION & PUBLIC WORKS DEPARTMENT

Pavement Design Standards Manual

2005

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GREGORY GEOTECHNICAL

PREFACE

In January of 2005 the Fort Worth City Council authorized the Director of the Transportation and Public Works Department to prepare a Pavement Design Standards Manual to guide the design and construction of streets within the City and its anticipated growth area.

The first step in the preparation of this Pavement Design Standards Manual was to determine the criteria upon which the planning and subsequent design and construction would be based. This Manual is compiled for the purpose of establishing uniform criteria and procedures for the design of all public streets to be constructed by and for the City of Fort Worth.

In the preparation of this Manual, the American Association of State Highway and Transportation Officials (AASHTO), “Guide for Design of Pavement Structures” (1993 Edition), and the American Society for Testing and Materials (ASTM) have been of considerable value as reference sources.

The Manual was prepared by Garry H. Gregory, PE, Gregory Geotechnical, in consultation with the Pavement Design Standards Committee, which consisted of City staff and local consulting and development engineers:

- George Behmanesh, Assistant Director, TPW (Chair)
- Jim Amick (Neel-Schaffer, Inc.)
- Chris Brooks (Wade & Associates, Inc.)
- Ken Davis (Marlin Atlantis)
- James Deotte (Deotte, Inc.)
- Carl Dezee (Kimley-Horn & Associates, Inc.)
- Roy Grant (Fugro Consultants LP)
- Don Harrelson (BHB Engineering & Surveying)
- Ty Hilton (Teague Nall & Perkins, Inc.)
- Richard Kelley (Freese & Nichols, Inc.)
- Gerald Lemons (Retired, Carter & Burgess Inc.)
- Richard Payne (Carter & Burgess, Inc.)
- Joe Schneider (Hillwood Development Corporation)
- Robert Stengele (Turner Collie & Braden, Inc.)
- Richard Argomaniz (Professional Engineer, DOE)
- Najib Fares (Infrastructure Manager, TPW)
- Ryan Jeri (Material Testing Lab Manager, DOE)
- John Kasavich (Professional Engineer, Water)

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Pavement Design Standards Manual
Report No. RM05002
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City of Fort Worth
Transportation and Public Works Department
1000 Throckmorton Street
Fort Worth, Texas 76102

Attention: Mr. George Behmanesh, P. E.

Geotechnical Engineering Services
Pavement Design Standards Manual
Fort Worth, Texas

Submitted here is the completed Pavement Design Standards Manual for the City of Fort Worth, Transportation and Public Works Department. This manual was prepared in general accordance with the scope of services described in our Letter Agreement No. P05003, dated April 22, 2005.

The manual was prepared in consultation with City staff and includes revisions recommended in the committee meeting of June 15, 2005. The manual is being transmitted in electronic format for your interim use. Hard copies of the manual will follow by FedEx. We appreciate the opportunity to continue to provide professional services to the City of Fort Worth. Please contact us if you have any questions or if we may be of further service at this time.

Respectfully Submitted,

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Garry H. Gregory

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1.0 Purpose

This Pavement Design Standards Manual (Pavement Manual) describes minimum standards to be used for design of pavements for all streets in the jurisdiction of the City of Fort Worth. This manual was developed for and in coordination with the City of Fort Transportation and Public Works Department (City). Pavement Design as used in this manual refers to the design of pavement subgrades, including related earthwork, subgrade modification or stabilization, thickness design of pavement sub-bases, bases, and structural components including reinforcing steel and joints where required, pavement subsurface drainage systems, and trench embedment and backfill for utility trenches as they relate to pavement performance. This manual does not address geometric design of streets, traffic signalization, or design of actual utilities, which are covered in other City standards.

1.2 Format

The text of the Pavement Manual is contained in Sections 1 through 7. Subheadings are provided in each section as appropriate. At least one subheading is provided in each section. A list of references is presented immediately following the end of the manual text. The reference list contains both cited references that are specifically listed in the text, and general references that are relevant to the design standards, but are not specifically cited in the text. Cited references are numbered according to the section in which they first appear, and are repeated thereafter as required.

All drawing details, plates, and large tables are contained in Append A. Special Technical Specifications are included in Appendix B. The alpha-numeric plate and table numbers identify the appendix in which they appear. Small tables of less than one page in length may appear in the body of the text and are numbered according to the section in which they occur. The date (month and year) in the footer of the main text is the issue month and year of the Pavement Manual. Dates on plates and tables in the appendices may be earlier dates that represent the actual date when the particular item was completed. Selected terms used in the Pavement Manual, such as “Engineer,” are specifically defined in the Definitions section, at the end of the text portion of the manual.

Units used in the Pavement Manual are based on the U.S. Customary (English) foot-pound-second system and may include tons per square foot (tsf), kips (1 kip = 1,000 pounds), kips per square foot (ksf), pounds per square foot (psf), pounds per cubic foot (pcf), pounds per square inch (psi), and other English units as appropriate.

2.1 Requirements for Geotechnical Engineering Services

All pavement construction and reconstruction projects shall have a detailed geotechnical engineering study performed. The following guidelines shall be considered as a minimum scope of geotechnical engineering services for pavement projects. The following guidelines for minimum scope of geotechnical engineering services are not intended to replace the professional judgment of the geotechnical engineer for any specific pavement project. The scope may need to be expanded or modified on a case by case basis as determined necessary and appropriate by the geotechnical engineer of record. However, the requirements listed herein shall be considered minimums and the scope of geotechnical engineering services shall not be less unless specifically approved otherwise in writing by the Engineer.

- Perform soil borings with continuous thin-walled (Shelby) tube sampling to a minimum depth of 10 feet or to the top of rock, whichever is less. Deeper borings will be required if deeper utilities are involved in the design. In the area of proposed utilities, the depth of borings shall be a minimum of 2 pipe diameters below the proposed pipeline, but not less than 3 feet below the proposed pipeline. The required number of borings is highly site and project specific, and the maximum spacing and minimum number of borings shall be determined by the geotechnical engineer on a case by case basis. In any event the number of borings shall be sufficient to adequately cover the various soil types and zones and shall provide generally representative samples of the subgrade materials. Boreholes shall be properly backfilled with sand backfill, grout, or hydrated bentonite chips, with the type of backfill being determined on a case by case basis by the geotechnical engineer. The top 2 feet of boreholes shall be plugged with hydrated bentonite chips or grout, and in existing paved areas a minimum of the top 6-inches shall be patched with concrete mix or cold mix asphalt, depending on the type of pavement structure. Boreholes in existing or proposed pavement areas shall not be backfilled with soil cuttings, since significant future settlement of the soil cuttings in the borehole is almost certain to occur.
- The laboratory testing program shall include classification tests consisting of Liquid and Plastic Limits, and percent passing the Number 200 Sieve for clayey soils, and shall include gradation tests for granular soils. These tests shall be performed in each different stratum in each boring, with a minimum of one set of tests in all borings.

- Moisture content and pocket penetrometer tests shall be performed at approximately 2-foot intervals in cohesive soils and pocket vane shear tests shall be performed on selected softer clay soils in each stratum, wherever pocket penetrometer test results are less than 3 tsf.
- Unconsolidated-Undrained (UU) triaxial shear tests shall be performed on representative clay samples whose moisture contents are near or above the Plastic Limit. A minimum of one UU triaxial test shall be performed in each boring. If a sufficient number of specimens do not have natural moisture contents near or above the Plastic Limit, a sufficient number of specimens shall be back-pressure saturated or soaked under confined conditions to increase the moisture content prior to testing. The undrained shear strength results from the UU triaxial tests can be correlated with CBR and resilient modulus values for pavement thickness design (refer to Plate B.1). In lieu of these correlations, actual CBR testing may be performed.
- Percent swell (free swell) tests shall be performed in the higher plasticity clays. These tests shall be performed on specimens with moisture contents at or below the Plastic Limit. If required, a sufficient number of specimens shall be incrementally air dried prior to trimming into the test rings to reduce the moisture contents to or below the Plastic Limit. Swell tests on soils with moisture contents significantly above the Plastic Limit will not be of value in determining swell potential, since the specimens will have already swelled under the higher moisture content.
- Lime or cement series tests shall be performed on representative samples if these stabilizers are anticipated, and soluble sulfate tests shall be performed in this case to determine the potential for sulfate in the soils to cause heave reaction with lime or cement. Soluble sulfate tests shall be performed at the minimum rate of one test in every other boring, with a minimum of three tests.
- The geotechnical report shall address the general geology of the site and discuss any geologic hazards related to the pavements, such as expansive soils or similar items. The geotechnical report shall also include appropriate recommendations for subgrade stabilization, related earthwork, and pavement thickness design, and shall address internal pavement drainage including recommendations for geosynthetics and permeable bases where applicable.

2.2 Qualifications

The geotechnical engineering services shall be performed under the direct supervision of a Texas Licensed Professional Engineer qualified by education and experience to practice geotechnical engineering and currently practicing geotechnical engineering on an essentially full time basis.

3.1 General

Improvement or treatment of soil subgrades for support of pavement systems shall generally be considered to consist of two categories, those being Modification and Stabilization. Modification will be considered to consist of treatment of soils with lime, Portland cement or similar materials at relatively low percentage (typically 2 to 6 percent) by dry weight to reduce PI (plasticity), reduce volume change, and increase workability. Stabilization will be considered to consist of treatment of soils with lime, Portland cement, or similar materials at higher percentage (typically 4 to 12 percent) by dry weight to increase strength, as well as provide the improvements listed above for Modification. The improvement of subgrades with appropriate geosynthetics and/or permeable bases, and lime slurry pressure injection (LSPI) will be considered in the category of Stabilization.

3.2 Requirements for Modification or Stabilization

Modification or Stabilization of the subgrade will be required for any project which has any of the following conditions.

- The raw subgrade soil has a laboratory CBR value less than 3.
- The street is an arterial or major collector and the raw subgrade soil has a laboratory CBR value less than 5.
- The Swell Ratio (S_R) of the subgrade is equal to or greater than 1, as defined below.

In determining requirements for Modification or Stabilization, the CBR value shall be the laboratory CBR value for specimens compacted to the specified density for the subgrade soil and soaked for 96 hours prior to penetration testing in general accordance with ASTM D 1883. Alternatively, the CBR values may be estimated by correlated to UU triaxial tests on soaked or backpressure saturated specimens as discussed in Section 2 of this manual.

The S_R shall be defined as the percent swell (expressed as a decimal) multiplied by the estimated depth (in inches) of the active zone of the expansive soil. For example, for an active depth of 96 inches and a free swell value of 2 percent, S_R = 0.02 x 96 = 1.92. Since the S_R value is greater than 1, the subgrade requires Modification or Stabilization. The active zone shall be estimated by the geotechnical engineer, but shall not be taken as less than 60 inches, unless non-expansive soil is present at a lesser depth and continues to the water table or to rock. The percent swell shall be determined from the results of free swell tests performed at overburden pressure. In the event that the natural moisture content of the free swell specimen is above the plastic limit, the specimen shall be air dried to below the plastic limit prior to testing as discussed in Section 2 of this manual.

3.3 Modification and Stabilization Methods

3.3.1 Modification

Modification shall be considered to consist of treatment of the subgrade soil with lime, Portland cement, or similar products in the general application range of 2 to 6 percent by dry weight, as previously stated. This manual specifically addresses Modification only with lime and Portland cement. However, other products that can be fully demonstrated to produce substantially the same results by laboratory testing and historical performance may be approved by the Engineer on a case by case basis.

Subgrade Modification with lime or Portland cement shall be in accordance with Special Technical Specification “Subgrade Modification / Stabilization” in Appendix C. The required design thickness of Modification shall be determined as part of the pavement thickness design discussed in Section 4 of this manual. The minimum thickness of Modification shall be 6 inches.

3.3.2 Stabilization

Stabilization shall be considered to consist of treatment of the subgrade soil with lime, Portland cement, or similar products in the general application range of 4 to 12 percent by dry weight (as determined on a case by case basis), and installation of geosynthetics with or without permeable bases, as previously stated.

3.3.2.1 Stabilization with Lime or Portland Cement – Stabilization with lime or Portland cement shall be in accordance with Special Technical Specification “Subgrade Modification / Stabilization” in Appendix C. The required design thickness of Stabilization shall be determined as part of the pavement thickness design discussed in Section 4 of this manual. The minimum thickness of Stabilization shall be 6 inches.

3.3.2.2 Stabilization with Geosynthetics and Permeable Bases – Stabilization with geosynthetics and permeable bases shall consist of installation of appropriate geosynthetics on the compacted subgrade, followed by permeable base material consisting of crushed stone, either unbonded or bonded with Portland cement to form Cement Treated Permeable Base (CTPB).

3.3.1 Increase in Subgrade Support Value

3.3.3.1 Modification - Modification shall not be considered to increase the long-term subgrade support value. Modification is intended to reduce plasticity, improve workability, and provide an improved working surface for pavement construction.

3.3.3.2 Lime or Cement Stabilization - Increase in long-term subgrade support by Stabilization (i.e. increase in CBR value) with lime, Portland cement, or similar products shall be based upon either CBR testing and/or UU triaxial testing of the subgrade soils at the specified percentage of admixture. The tests shall be performed with the specimens in a soaked or saturated condition. A minimum of 3 tests shall be performed for each soil type and for each admixture percentage. The testing approach shall be in general accordance with ASTM D 4609 – "Standard Guide for Evaluating Effectiveness of Admixtures for Soil Stabilization," except as modified in this Section.

Laboratory CBR values (or CBR values correlated with UU triaxial tests) of lime or Portland cement stabilized subgrade soils shall be adjusted to a long-term CBR value in accordance with Equation 3.1.

$$CBR_{adj} = \frac{CBR_{test}}{0.45\ln(D_L)} \tag{3.1}$$

Where: CBR_{adj} = Long-term CBR value adjusted for design life of pavement
CBR_{test} = Laboratory CBR value from saturated or soaked specimens
D_L = Design Life of pavement in years

This equation takes into consideration the long-term loss of CBR support value of the lime or cement treated subgrade due to leaching of the admixture, breakdown of bonding, and loss of strength with time. Accordingly, the longer the pavement design-life, the lower the adjusted CBR will be with respect to the initial laboratory CBR. The adjusted CBR is essentially the average CBR available for subgrade support over the design life of the pavement. Application of CBR values to pavement thickness design, correlation with resilient modulus values, and similar items are discussed in Section 4 of this manual.

3.3.3.3 Stabilization with Geosynthetics and Permeable Base – Increase in long-term subgrade support (i.e. increase in CBR value) with geosynthetics and permeable base shall be based upon criteria presented in this subsection.

When a weak subgrade soil with CBR value less than 11 is reinforced with a *geotextile or a geotextile in combination with a geogrid* the composite CBR value of the subgrade soil and geosynthetic is significantly greater than the CBR value of the raw subgrade soil alone. This is applicable for those cases where the geosynthetics are placed directly on the prepared subgrade, followed by a minimum of 3 inches of permeable base. The effective CBR value of the subgrade soil and geosynthetics may be determined from Plates B.2 and B.3 in Appendix B. This effective CBR is referred to as the geosynthetic-modified (GSMOD) CBR. The GSMOD CBR value for geotextile only is determined from Plate B.2, and for geotextile and geogrid combined from Plate B.3. To determine the GSMOD CBR, select the raw subgrade CBR on the horizontal axis, then proceed vertically to the curve and project horizontally to the GSMOD Factor on the vertical axis. The GSMOD CBR is the sum of the raw subgrade CBR and the GSMOD Factor. For example, if a geotextile and geogrid are used for a subgrade with a raw soil CBR value of 3, enter Plate B.3, select raw subgrade CBR of 3, proceed vertically to the curve and project horizontally to the vertical axis to read 7.2 for the GSMOD Factor. The GSMOD CBR is then 7.2 + 3 = 10.2. This GSMOD CBR can then be used instead of the raw subgrade CBR for pavement thickness design as described in Section 4 of this manual. The GSMOD CBR value is only valid when the geosynthetics are used in combination with a minimum of 3 inches of permeable base. *However, the GSMOD CBR value does not include the permeable base.* The permeable base has a separate CBR value as described below. The geotextile and geogrid shall be in accordance with appropriate requirements of the Special Technical Specifications in Appendix C.

The GSMOD CBR for a raw subgrade improved with a *geocomposite blanket drain* can be determined from Figure 3.3. This figure is applicable for raw subgrade CBR values of 5 or less, and when a minimum of 2 inches of permeable base is used over the geocomposite blanket drain. The geocomposite blanket drain shall be placed directly on the prepared subgrade. The GSMOD is determined in the same manner as previously described for geotextiles and geogrids, and is the combination of the raw subgrade CBR value and the GS Factor. The geocomposite blanket drain shall be in accordance with appropriate requirements of the Special Technical Specifications in Appendix C.

When *permeable base material* (bonded or unbonded) is used as part of the subgrade stabilization process, and not as part of the required structural thickness of the pavement, the CBR value of the permeable base shall be determined by laboratory CBR testing of the ***unbonded*** permeable base material. A minimum of 3 tests shall be performed for each permeable base material. The long-term CBR value for the permeable base material shall be the average of the three tests or 80, whichever is less. In lieu of CBR testing, a long-term CBR value of 60 may be used for the permeable base material. The permeable base material shall be in accordance with appropriate requirements of the Special Technical Specifications in Appendix C.

Methods for determining the composite CBR (or correlated resilient modulus) value, including the raw subgrade and any stabilization components, are discussed in Section 4 – “Pavement Thickness Design” of this manual.

4.1 General

This section of the manual describes requirements for pavement thickness design for City streets. All streets shall be designed by an experienced and qualified engineer, licensed in the State of Texas. There shall be “minimum” pavement thickness requirements as presented in this section of the manual. *However there shall be no “standard” pavement designs and all pavements shall be individually designed to determine subgrade improvement and pavement thickness requirements based upon design traffic and design life as described in this section.* Structural components of streets shall be either Portland cement concrete (rigid pavement) or asphalt concrete, generally with crushed stone base (flexible pavement) as requested by the Engineer. Other pavement materials may be approved in advance by the Engineer on a case by case basis for unusual or special circumstances.

4.2 Traffic

Traffic shall be expressed as the number of “Equivalent Single Axle Loads” (ESALS) as defined by AASHTO (Reference 4.1). Traffic volume for pavement design shall be based upon actual traffic counts provided by the City, or in the absence of actual traffic counts, the minimum traffic volumes listed in Table 4.1 shall be used, as requested by the Engineer. The Engineer may designate a different traffic volume on a case by case basis for other conditions or situations.

Table 4.1 – Minimum Design Traffic and Design Life for Pavements

Street Classification	Annual ESALS	% Growth	Design Life - Years
Residential-Rural (low-volume)	25,000	0.0	25
Residential-Urban (high-volume)	35,000	0.0	25
Collector	100,000	1.5	25
Industrial	200,000	2.0	30
Arterial	300,000	2.5	30

4.3 Design Methods and Procedures

Pavement thickness design shall be performed for each individual street based upon the American Association of State Highway and Transportation Officials (AASHTO) “Guide for Design of Pavement Structures,” 1993 Edition (Reference 4.1), herein referred to as the

AASHTO Design Guide, except as modified in this section of the manual. Later editions of the same publication may be adopted by the City from time to time as appropriate to replace older editions when newer editions are finalized and released for public use. This method shall be used for both rigid and flexible pavement thickness design. Pavement thickness, including appropriate subgrade stabilization as presented in Section 3 of this manual, shall be designed using the AASHTO Design Guide and full documentation shall be provided to the City by the pavement designer. Computer programs that fully utilize the methods and procedures described in the AASHTO Design Guide are encouraged and may be used for pavement design. In rare or unusual cases where the AASHTO Design Guide may not be technically appropriate, other equivalent methods may be approved in advance by the Engineer on a case by case basis. In this event, full documentation of the design must be provided to the City.

4.4 Reviews by City Staff

City Staff may from time to time review pavement designs for City streets submitted in accordance with this section. However, any such reviews shall be conducted as a means to verify in general if the designs have been performed using the general methods adopted by the City and shall not be considered as a detailed technical review of the design for adequacy, accuracy, or completeness. The engineer performing the pavement design shall remain responsible for the technical adequacy, accuracy, and completeness of the pavement design and shall not be relieved of any responsibility for such as a result of the City's review.

4.5 Requirements for Rigid Pavements

4.5.1 Drainage Coefficients

Appropriate drainage coefficients as defined in Section II of the AASHTO Design Guide shall be used in rigid pavement design. Pavements consisting of Portland cement concrete placed directly on clay subgrade soils or directly on lime or cement modified or stabilized clay subgrades without a permeable base layer do not allow for adequate internal pavement drainage. The "Quality of Drainage" as define in Part II, Table 2.5 of the AASHTO Design Guide for such conditions shall be considered to be "Very Poor" with percent of time that the pavement structure is exposed to moisture levels approaching saturation to be "Greater Than 25%." Accordingly, the maximum allowable drainage coefficient (C_d) for such conditions shall be 0.70.

The maximum allowable drainage coefficient for rigid pavements placed over permeable base with a minimum thickness of 3 inches and tied into an edge drain system shall be 1.15, and for a minimum thickness of permeable base of 5 inches and tied into an edge drain system shall be 1.25.

4.5.2 Reinforcement

All rigid pavements shall be jointed reinforced concrete pavements (JRCP) or continuously reinforced concrete pavements (CRCP). Only steel reinforcement will be allowed. No plain jointed concrete pavements (JCP) will be allowed. Continuously reinforced concrete pavements (CRCP) will be allowed only if approved in advance in writing by the Engineer.

Reinforcement for JRCP shall be designed in accordance with Part II – Section 3.4 of the AASHTO Design Guide, except maximum spacing for number 3 reinforcing bars shall be 24 inches center to center, and for larger bars the maximum spacing shall be 36 inches center to center.

Reinforcement for CRCP (if CRCP is allowed by the Engineer) shall be designed in accordance with Part II – Section 3.4 of the AASHTO Design Guide, except transverse reinforcement shall have a maximum spacing for number 3 reinforcing bars of 24 inches center to center, and for larger bars the maximum spacing shall be 36 inches center to center.

Friction Factors between pavement slab and material beneath slab shall be in accordance with Part II – Table 2.8 of the AASHTO Design Guide, except the friction factor for natural subgrade shall be no less than 1.0.

4.5.3 Load Transfer Devices (Dowels)

Load transfer devices (dowels) shall be used across all transverse joints and all longitudinal contraction joints, as defined in subsection 4.5.4 of this manual. Dowels shall be smooth steel dowels, and shall be cut or fabricated in a manner that will not leave a “bulge” or otherwise deformed end on the dowel that could prevent the dowel from free slippage in the pavement. The minimum dowel diameter in inches shall be 0.125 times the slab thickness in inches or

0.75-inch diameter, whichever is greater. Minimum dowel spacing shall be 12 inches center to center and minimum dowel length shall be 18 inches, except the minimum length shall be 20 inches at expansion joints. Refer to subsection 4.5.4 of this manual for joint requirements related to dowels.

4.5.4 Pavement Joints

Joints for rigid pavements shall be defined as follows:

1. *Contraction Joint* – A saw-cut contraction joint across which no reinforcing steel is placed. Transverse contraction joints require smooth dowels for load transfer. Dowels shall be centered on the joint. The dowels are placed in prefabricated chairs prior to concrete placement and the saw joint is cut over the dowel center line following placement of concrete. Contraction joints may be transverse or longitudinal as required.
2. *Dummy Saw Joint* – A saw-cut joint across which the reinforcing steel is continuous, and which does not have dowels. This type of joint includes both transverse and longitudinal joints. Dummy saw joints are cut following placement of concrete.
3. *Construction Joint* – A construction joint is a formed joint completely through the pavement thickness that is necessary at termination points of concrete placement. A construction joint may consist of both transverse and longitudinal joints. Construction joints shall have no reinforcing steel across the joint. Smooth dowels shall be placed across all construction joints as described for contraction joints.
4. *Expansion Joint* – Expansion joints are joints that extend through the full thickness of the pavement and completely through all adjacent curb and gutter sections, and are filled with expansion-joint material. Expansion joints shall be a minimum of 0.75-inch wide. No reinforcing steel shall extend across expansion joints. Expansion joints shall have smooth dowels for load transfer as described for contraction joints, except dowels shall be a minimum of 20 inches in length.

4.5.5 Joint Placement

4.5.5.1 Transverse Contraction Joints – Transverse contraction joints shall be placed at a maximum spacing in feet of 5 times the pavement slab thickness in inches. The ratio of the transverse contraction joint spacing to pavement width shall not exceed 1.25.

4.5.5.2 Longitudinal Contraction Joints - Longitudinal contraction joints shall be used if the pavement width in feet from the centerline construction joint to the pavement edge is greater than 5 times the pavement slab thickness in inches. This typically occurs only where turning lanes or similar additional lane widths are required.

4.5.5.3 Dummy Saw Joints – Transverse dummy saw joints shall be placed half-way between transverse contraction joints. Longitudinal dummy saw joints shall be placed along the center line of all pavements with a width in feet less than or equal to 5 times the pavement slab thickness in inches and which do not have a longitudinal construction joint along the center line.

4.5.5.4 Construction Joints – Transverse construction joints shall be minimized. Transverse construction joints will be allowed only where specifically shown on the drawings or specified, unless approved otherwise by the Engineer for emergency termination of concrete placement. Where necessary, transverse construction joints shall coincide with the location of what would otherwise be a transverse contraction joint. Construction joints shall be mandatory along the centerline of all rigid pavements.

4.5.5.5 Expansion Joints - Expansion joints shall be placed at all intersections, where pavements abut structures or similar items, and otherwise at a maximum spacing of 600 feet.

4.5.6 Minimum Thickness for Rigid Pavements

All rigid pavements shall be specifically designed to determine required thickness of the pavement slab. However, no rigid pavement slab shall be less than 6 inches in thickness. Minimum thickness for rigid pavements placed directly on the subgrade or directly on lime or cement (or similar materials) treated subgrade without permeable base materials shall be as shown in Table 4.2. Calculated pavement design thickness shall be rounded up to the nearest half-inch.

Table 4.2 – Minimum Design Thickness of Rigid Pavements without Permeable Base	
Street Classification	**Minimum Thickness - Inches**
Residential	6
Collector	7
Industrial	8
Arterial	8

The minimum thickness of rigid pavements with permeable base and/or a geocomposite blanket drain, with an edge drain system and geosynthetic separator layer on the subgrade may be less than the minimum thickness shown in Table 4.2 for pavements without permeable base if the pavement and permeable base system is fully demonstrated to have the same or greater design life and traffic capacity as the minimum thickness shown in Table 4.2 for pavements without permeable base. The equivalent design life and traffic capacity must be fully demonstrated by thickness design comparisons performed using the AASHTO Design Guide. However, no rigid pavement shall be less than 6 inches in thickness under any circumstance.

4.6 Requirements for Flexible Pavements

4.6.1 Drainage Coefficients

Appropriate drainage coefficients as defined in Section II of the AASHTO Design Guide shall be used in flexible pavement design for pavements with base materials. Pavements without a permeable base layer connected to an edge drain system do not allow for adequate internal pavement drainage. The “Quality of Drainage” as define in Part II, Table 2.4 of the AASHTO Design Guide for such conditions shall be considered to be “Very Poor” with percent of time that the pavement structure is exposed to moisture levels approaching saturation to be “Greater Than 25%.” Accordingly, the maximum allowable value of “m_i” for modifying structural layer coefficients for such conditions shall be 0.40.

Pavements consisting of full-depth asphalt concrete placed directly on clay subgrade soils or directly on lime or cement modified or stabilized clay subgrades without a permeable base layer do not allow for adequate internal pavement drainage. Accordingly, for such conditions the CBR value of the raw subgrade soil and any lime or cement (or similar material) stabilized layers shall individually be reduced to 80 percent of the CBR_{adj} value determined as described in Section 3 of this manual.

The maximum allowable drainage coefficient for flexible pavements placed over permeable base with a minimum thickness of 3 inches and tied into an edge drain system shall be 1.30, and for a minimum thickness of permeable base of 5 inches and tied into an edge drain system shall be 1.40.

4.6.2 Base Requirements for Flexible Pavements

Base material (flex base) for flexible pavements shall consist of crushed stone material as specified in the Special Technical Specifications in Appendix C. The flex base shall be designed to meet filter criteria between the base material and the permeable base layer if a permeable base layer is used. Where the flex base is placed directly on the subgrade, including lime or cement (or similar material) modified or stabilized subgrade, a geotextile separator shall be placed on the subgrade at the contact between the flex base and the subgrade. The geotextile shall be as specified in the Special Technical Specifications in Appendix C.

4.6.3 Minimum Thickness for Flexible Pavements

All flexible pavements shall be specifically designed to determine required thickness of the pavement including any base layers. Full-depth asphalt concrete pavement shall not be less than 6 inches in thickness. Flexible pavements with asphalt concrete over flex base shall have a minimum asphalt concrete thickness of 6 inches and a minimum flex base thickness of 6 inches.

5.1 General

This section of the manual describes specific pavement construction requirements related to design of the pavements. These construction requirements shall be incorporated into the pavement construction documents by the pavement designer. This section is not intended to direct the contractor with respect to means, methods, sequences, or procedures of construction, and specifically does not address safety programs or requirements of the contractor. These items are the sole responsibility of the contractor. This section does set forth specific pavement requirements which must be accomplished during the construction phase of the pavement project. All construction of pavements, including but not limited to items covered in this section of the manual, shall be in conformance with applicable portions of the Special Technical Specifications in Appendix C.

5.2 Proof Rolling and Undercutting of Subgrade

Proof rolling of the subgrade to detect soft or otherwise unsuitable subgrade areas shall be performed on all pavement subgrades when the subgrade has been excavated or filled to the approximate grade, and prior to modification or stabilization. Soft or otherwise unsuitable subgrade shall be undercut and backfilled with suitable material. Proof rolling, undercutting, and undercutting backfill shall be in accordance with the Special Technical Specifications in Appendix C.

5.3 Drainage

Pavement subgrade areas shall be sequenced and constructed in a manner that will provide positive drainage of the subgrade at all times during construction. This includes any sub-base layers, base layers, permeable base, geosynthetics, or other similar items. To this end the documents shall require the contractor to either construct the outlet portions of pavement subsurface drainage ahead of subgrade modification to prevent ponding or accumulation of water on or adjacent to the subgrade, or to provide temporary drains including sumps and pumps where necessary. Construction shall be performed in a manner that will expose the subgrade to the weather a minimum amount of time. Modification or stabilization shall follow closely behind subgrade preparation and pavement surfacing shall closely follow placement of stabilization, including any permeable base layers, sub-surface drainage systems, and geosynthetics.

5.4 Saw Cutting of Joints

The sequence and time frame for saw cutting of joints is of critical importance to limit pavement cracking. Sawing of joints shall begin as soon as the concrete has hardened sufficiently to permit sawing without excessive raveling. All saw joints shall be completed before uncontrolled shrinkage cracking occurs and shall be completed as soon as possible under hot weather conditions and within a maximum of 24 hours after saw cutting begins under cool weather conditions. The first transverse contraction joint saw-cut shall be made near the center of the entire section placed on that particular day. The next two transverse contraction joint saw cuts shall then be made approximately half way from the center saw cut to the end of the section on each side. The process shall be repeated successively on each side of previously cut transverse contraction joints to consistently cut in half the remaining panels with each saw cut. This process shall be continued until all transverse contraction joint saw cuts are completed. Then all transverse dummy saw joints shall be cut beginning with the one nearest the end where concrete placement began and continuing in the direction of the concrete placement until all dummy saw joints are completed. This overall saw-cutting sequence will result in providing the most rapid and effective stress relief for the pavement, and will help limit random shrinkage cracking. The Joints shall be cleaned and sealed as specified in the Special Technical Specifications in Appendix C before opening to traffic.

SECTION 6
PAVEMENT DESIGN STANDARDS
QUALITY CONTROL / QUALITY ASSURANCE

6.1 General

This section of the manual covers requirements for quality control and quality assurance during the construction phase of pavement projects. Quality Control (QC) refers to quality control testing and verification activities performed by the construction contractor or by third-parties retained by the contractor, to assist the contractor in verifying conformance with the contract documents on an essentially continuous basis. Quality Assurance (QA) refers to quality assurance testing and observation performed by the City or by third-parties retained by the City, generally on a regular but intermittent basis, as a means to verify conformance with the contract documents. The results of the contractor's QC tests shall not be considered as official results and will be considered informational only. The results of the City's QA test results shall be the official test results and in the event of a conflict between QC test results and QA test results, the City's QA test results shall govern and take precedence. This section of the manual is intended to establish minimum requirements for QC and QA. Additional items may be required for specific projects and some items or materials listed in this Section of the manual may not be used on all projects. However, to the extent that the items do occur on a project, the requirements set forth in this section shall be considered as minimums. This manual is not intended to cover general submittal items that may be required from the contractor by the contract documents, and any submittal requirements listed in this section is not all inclusive.

6.2 Quality Control

The Contractor shall provide the following specific QC items, including submittals to City.

1. Mix Designs for Portland cement concrete and asphalt concrete, including test series.
2. Mix Designs on bonded permeable base (CTPB)
3. Particle Size Analysis (gradation) tests, and durability and soundness tests on aggregate materials, including flex base, permeable base, and drainage aggregate, and providing bulk samples for QA testing . Aggregate source owner/agent notarized non-contamination certification shall also be required.
4. Test series on any specified Earth Fill from off-site borrow sources, including the following (refer to Special Technical Specifications on Earthwork):
    a. Liquid and Plastic Limits (Atterberg Limits) on clayey soils
    b. Percent passing the No. 200 sieve on clayey soils.
    c. Hydrometer Analysis for silt content (*only if specifically required in contract documents*) on fine grained soils
    d. Double Hydrometer Analysis for dispersion determination on low-permeability barrier soils (*only if specifically required in contract documents*)
    e. Moisture Density Relationship (ASTM D 698 – Standard Proctor) on clayey soils and Maximum Index Density tests (ASTM D 4253) on sandy soils not suitable for Proctor testing, as determined by the Engineer.

f. Hydraulic Conductivity on specimens compacted to specified moisture and density range (*applies to Non-Expansive Earth Fill only*).
g. Percent (free swell) on specimens compacted to specified moisture and density range (*applies to Non-Expansive Earth Fill only*).
h. Particle size analysis (gradation) including determination of uniformity coefficient (C_u) and coefficient of curvature (C_c), liquid limit and plastic limit tests (where applicable), and visual classification of angularity with magnifying lens or hand microscope on sandy soils.
i. Analytical Laboratory EPA contaminant scan.
j. Borrow pit owner/agent notarized non-contaminant certification.
k. Providing bulk samples for QA testing by City, if requested.

5. Contractor shall also be required to provide field and laboratory QC testing during construction on the same general items as listed below under Quality Assurance to the extend deemed necessary by the contractor to facilitate the contractor's construction schedule and to consistently verify compliance with the contract documents.

6.3 Quality Assurance

The City will provide the following QA items, including providing test results to the contractor where applicable.

Earthwork

1. Initial classification tests and moisture density tests shall be performed on all on-site materials to be used for earth fill and on materials occurring in cuts at the subgrade level. Classification tests on clayey soils shall consist of liquid limit and plastic limit tests and percent passing the number 200 sieve tests. Classification tests on sandy soils shall consist of particle size analysis including determination of uniformity coefficient (C_u) and coefficient of curvature (C_c), liquid limit and plastic limit tests (where applicable), and visual classification of angularity with magnifying lens or hand microscope. Moisture density tests shall consist of Standard Proctor (ASTM D 698) on clayey soils and Maximum Index Density tests (ASTM D 4253) on sandy soils not suitable for Proctor testing, as determined by the Engineer. All of these tests shall also be performed periodically on any borrow soils imported to the site, with the frequency being as specified in the contract documents or as requested by the Engineer.
2. Field moisture-density tests shall be performed on all compacted earth fill. The minimum frequency of testing shall be one test per lift for each 2,500 square feet of lift surface area, with a minimum of 2 tests per lift. Subsequent test locations shall be offset from the test locations in the previous lift.

3. Field moisture-density tests shall be performed on all utility trench bedding, embedment, and backfill. The minimum frequency of testing shall be one test per lift per 150 linear feet of trench length, with a minimum of 2 tests per lift.

Lime or Portland Cement (or similar materials) Modification

1. When at or near the final subgrade elevation, representative samples shall be obtained from the soil subgrade and shall be tested to determine the quantity of lime or cement (or similar materials) required for the actual subgrade soils.
2. The placement and compaction of lime or cement treatment shall be observed on an essentially continuous basis, and delivery tickets shall be collected from each transport truck as a means to verify lime or cement quantities being used relative to areas being treated.
3. Samples shall be collected from the pulverized treated mixture at the site and shall be tested for gradation requirements. The minimum frequency of testing shall be one test per 150 linear feet per lane width per each 8-inches or less of treated depth, with a minimum of 2 tests per area.
4. Specimens from the samples collected for gradation tests shall also be tested for pH. A pH test shall also be performed on each different soil prior to admixture application to establish a baseline pH value.
5. Samples of the treated materials shall be collected after final pulverization and tested for moisture density relationship (ASTM D 698) for each soil type being treated.

Lime or Portland Cement (or similar materials) Stabilization

1. When at or near the final subgrade elevation, representative samples shall be obtained from the soil subgrade and shall be tested to determine the quantity of lime or cement (or similar materials) required for the actual subgrade soils.
2. All of the above tests and frequencies listed above for Modification shall also be performed for Stabilization with Lime or Portland cement.
3. Samples shall be taken at the same frequency and at the same locations specified above for Modification and prior to hydration shall be compacted into cylindrical specimens to the specified density, cured and tested for unconfined compressive strength in general accordance with ASTM D 4609.

Pavement Materials

1. Review of required mix designs, certifications, and test results submitted by the contractor.
2. Survey elevations shall be taken on the subgrade and on top of base layers and on the top of pavement (concrete or asphalt) at the same locations to verify base and pavement

thickness. Survey shots shall be taken at 50-foot stations along the longitudinal pavement length and at random locations across the transverse width of the pavement with a minimum of one shot per lane width. Survey shots may be performed with actual survey instruments or with measurements from string lines between known points (such as side forms).

3. Cores shall be taken at any survey locations which indicate that the base or pavement thickness is deficient outside the allowable tolerance. In base materials which can be easily excavated by hand, the thickness can be verified by a small excavation rather than a core.
4. The fresh concrete shall be visually monitored during the placement of the concrete pavement for general compliance with the construction documents (plans and specifications). The monitoring shall include verifying the proper mix design is being used, the slump remains within the specified limits, and the water addition does not create a slump greater than specified. If the concrete is visually inconsistent, then additional testing shall be performed to determine general compliance with the specifications. It should be understood that this may result in a delay to the placement due to the time required to perform the testing. The test results will be provided to the contractor and the contractor will decide if the concrete is to be “rejected.” If the test results indicate that the concrete mixture does not comply with the specifications and the contractor elects to place the concrete, additional compressive strength specimens shall be cast and tested.
5. Observation of reinforcing steel and dowel placement and support, and placement of concrete, to the extent determined necessary by the Engineer.
6. The field-testing of the fresh concrete for each 100 cubic yards or fraction thereof will include slump, air content, and ambient and concrete temperature determinations. Four concrete cylinders will be cast in conjunction with the field-testing for compressive strength determinations. Two cylinders shall be tested at 7 days and 2 at 28 days.
7. Field observations to establish a rolling pattern for asphalt concrete materials.
8. Asphalt concrete samples shall be taken daily for extraction, maximum theoretical specific gravity, and stability tests.
9. Field density testing of asphalt concrete shall be performed at the rate of one test at each 50-foot station with a minimum of one test per lane width at each 50-ft station for each base course and for the surface course.
10. Field density testing of asphalt concrete shall be supplemented by obtaining cores at maximum 300-foot intervals (to coincide with previous density test locations) to determine density and thickness for each base course and for the surface course.

7.1 Intent of the Pavement Manual

This manual specifies minimum standards required for design of pavements for City streets. The manual is not intended to replace the professional judgment of the engineer for any specific pavement project. The standards may need to be expanded or modified on a case by case basis as determined necessary and appropriate by the engineer of record for the particular project. However, the requirements listed herein shall be considered minimums and the requirements shall not be less unless specifically approved otherwise in writing by the Engineer.

7.2 Responsibility for Adequate Design

Although this manual describes minimum standards to be used in the design of pavements for City streets, it does not relieve the design engineer on any specific project from liability for the adequacy of the design. It is the responsibility of the design engineer to determine and implement additional standards or design methods over and above those described in this manual, if the engineer determines that additional standards or method are required for any specific project. Neither the City nor any of the engineers who have contributed to this manual shall be responsible for the adequacy of any pavement design performed by independent engineers and/or engineering firms retained by the City to provide design services related to City streets. Any reviews of pavement designs performed by the City or agents of the City on pavement design items submitted by independent engineers and/or engineering firms shall be understood to be reviews for general compliance with the intent of this manual and not for the purpose of determining adequacy or appropriateness of the design. Any approvals of such design submittals by the City or agents of the City shall not relieve the design engineer from responsibility and liability for adequacy of the design.

7.3 Deviations from Design Standards

When performing pavement designs for City streets and providing submittals of such to the City, the design engineer shall specifically point out any intended deviations from requirements set forth in this manual, and shall provide documentation and justification for the deviation. Written approval of the Engineer shall be required prior to actual implementation of any deviation by the design engineer from the requirements set forth in this manual. Other requirements determined to be necessary for a specific project by the design engineer which are *in addition* to requirements described in this manual and which *do not replace* such requirements shall not be considered as deviations from the design standards.

7.4 Precedence of Standards

The pavement design standards set forth in this manual shall take precedence over any existing City standards to the extent that the existing standards may be in conflict with requirements in this manual. In the event of a conflict between requirements in different sections or locations of this manual, the Engineer shall make a determination and/or provide clarification to resolve the conflict and the Engineer's decision shall take precedence. In the event of a conflict between the pavement design standards set forth in this manual and any existing or future local, state, or federal standards relating to pavement design, the requirements in this manual shall take precedence unless stipulated otherwise in writing by the Engineer.

7.5 Continuation and Revision of Standards

This manual or any parts thereof may be modified, updated, supplemented, expanded, or otherwise enhanced from time to time as the City determines the need. This manual shall remain in full force and effect without time limitation unless officially rescinded by the City. In the event that any part of this manual should be found to be in conflict with laws or regulations of competent jurisdiction or ruled to be invalid by a court authority of competent jurisdiction, the remainder of the manual shall remain in full force and effect, and the conflicting section or item shall be deleted or revised as required and as determined necessary by the Engineer.

7.6 Authorization for Use and Copyright

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